Beaverhead River and Splits

Enhanced Hydraulic Analysis and Floodplain Mapping Report

Beaverhead County, MT

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Beaverhead County, MT

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1. Introduction and Background

As part of a Mapping Activity Statement (MAS) contract initiated by the Montana Department of Natural Resources and Conservation (DNRC), Michael Baker International has completed detailed hydraulic analyses of the Beaverhead River and associated split flows in Beaverhead County. The purpose of this report is to document the hydraulic analyses and to provide results for subsequent floodplain mapping analyses. Results of the analyses will be incorporated into the Beaverhead County, Montana, and Incorporated Areas Digital Flood Insurance Rate Map (DFIRM) and Flood Insurance Study (FIS) (**Reference 1**). The data in this report will supersede the information presented in the January 5, 1982, FIRM and FIS at a later date. The effective study is being revised to incorporate updated topography and improved modeling techniques in order to provide more accurate flood hazard data. **Appendix A** includes the Certification of Compliance form that confirms the study has been completed using sound and accepted engineering practices and is in compliance with all contract documents.

A list of primary flooding sources included in this hydraulic study is provided in **Table 1-1**, and a map showing these flooding sources is provided in **Figure 1-1**. It should be noted that these primary flooding sources are not the only flooding sources included in this study. Many flows split from these flooding sources to form secondary flooding sources. These split flows are detailed in **Section 3** of this report. The study reaches have also been extended from the stream lengths published on the effective FIRMs and FIS. These additions constitute an additional 2.3 miles upstream and 19.4 miles downstream of the effective FIRMs and FIS on the Beaverhead River. An additional 0.5 miles of stream length has been added downstream of the effective FIRMS and FIS on the Dillon Canal. An additional 4.4 miles of stream length has been added downstream of the effective FIRMs and FIS on the Stodden Slough. The hydraulic analysis was completed using peak discharges for the 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance (10-, 25-, 50-, 100-, and 500-year) flood events, as well as the 1-percent-plus-annual-chance event.

Table 1-1: Flooding Sources Studied

Flooding Source	Upstream Limit	Downstream Limit	Reach Length (Miles)
Beaverhead River and Splits	Approximately 5600 feet downstream of the Confluence with Grasshopper Creek	Boundary of Beaverhead County and Madison County	41.6
Beaverhead River Overbank	Diversion structure at the Beaverhead River	Webster Lane	1.6
Dillon Canal	Poindexter Slough	Confluence with Blacktail Deer Creek	1.6
Guidici Ditch	Diversion structure at the Beaverhead River	Approximately 3800 feet downstream of Schuler Lane	1.8
Murray Gilbert Slough	Selway Slough	Approximately 4200 feet downstream of Schuler Lane at Schultz Lane	1.2
Poindexter Slough	Diversion structure at the Beaverhead River	Confluence with Beaverhead River	4.6
Poindexter Slough Overflow	Poindexter Slough	Confluence with Blacktail Deer Creek	2.0
Selway Slough	Diversion structure at the Beaverhead River	Approximately 1.4 miles downstream of Lost Trail	4.9
Stodden Slough	Approximately 1300 feet upstream of Arrigoni Lane	Confluence with Beaverhead River	7.8

For this project, multiple contractors were involved in the delivery of the many components that comprise the Technical Support Data Notebook (TSDN). Morrison-Maierle, Inc. completed the field surveying tasks for all flooding sources in the project area (**Reference 2**). The Morrison-Maierle tasks included the collection of cross-section survey data and hydraulic structure data. The topographic data collection was provided by Quantum Spatial (**Reference 3**). Pioneer Technical Services completed the hydrologic analyses for basins in the Beaverhead River watershed (HUC 8) (**Reference 4**). The topographic, field survey, and hydrologic data were reviewed and approved by FEMA during the process of the hydraulic and floodplain mapping analyses. Detailed information regarding Morrison-Maierle, Quantum Spatial, and Pioneer Technical Service contributions to the TSDN are included in the appropriate sections of this report.

1.1. Community Description

The City of Dillon is the county seat of Beaverhead County and is the largest community in the county. Beaverhead County is located in the southwest corner of Montana and is bordered by Lemhi County (Idaho) to the west; Ravalli, Deer Lodge, and Silver Bow Counties to the north; Madison County to the east; and Fremont and Clark Counties (Idaho) to the south.

Beaverhead County and the Town of Dillon have experienced only moderate population growth in the past 16 years. **Table 1-2** summarizes the Census population data (**Reference 5**). However, there has been more significant growth in the number of estimated housing units since 2000 with an additional 688 units added between 2000 and 2015. **Table 1-3** summarizes the census housing unit estimates (**Reference 6**). With the availability of improved terrain data, hydraulic modeling capabilities, and an additional 35 years of hydrology data, a restudy of the Beaverhead River and Tributaries is needed. This study will help to understand the impacts on living and working near the Beaverhead River and its tributaries, as well as the potential flood impacts on the physical assets of the community as noted above.

Table 1-2: Census Population Estimates

Community	2000 Population	2010 Population	% Increase from 2000 to 2010	2016 Population Estimate	% Increase from 2010 to 2016
Dillon	4,261	4,141	-2.8/%	4,257	2.8%
Beaverhead County	9,187	9,246	0.6%	9,401	1.7%

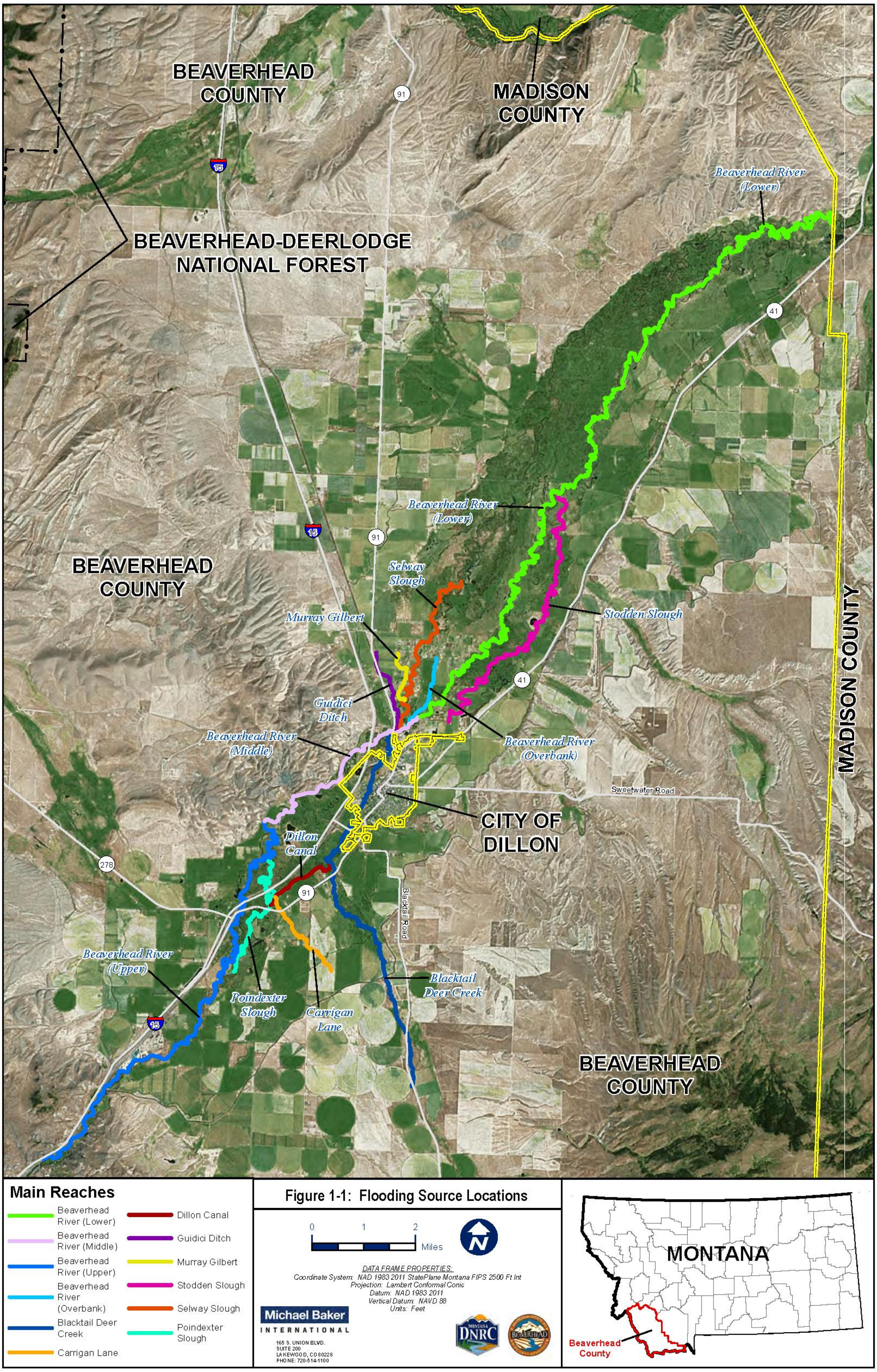
Table 1-3: Census Housing Units Estimates

Community	2000 Housing Units	2010 Housing Units	% Increase from 2000 to 2010	2015 Housing Units Estimate	% Increase from 2010 to 2015
Dillon	3,442	3,887	12.9%	3,971	2.1%
Beaverhead County	4,571	5,273	15%	5,259	-0.3%

Most severe flooding events in the Beaverhead River watershed (HUC 8 10020002) have been the result of spring snowmelt or ice jams. Historically, notable flooding within this watershed has occurred numerous times. Ice jam caused flooding in Dillon in 1937. Ice jams have had flooding effects in various parts of the county in 1949, 1951, and 1974. A rain on snow event in 1944 flooded areas in Dillon and damaged railroad and US Highway 91.

The Clark Canyon Dam, which sits approximately 10 miles upstream of the study area, was completed in 1964. As detailed in the Pioneer Hydrology Report, three USGS gages are operated in the study reach. Since the completion of the Clark Canyon Dam, the gage at Barretts has experienced 1 event exceeding the 1% chance annual flow (3,000 cfs in 1984). The gage at Dillon experienced one event exceeding the 10% chance annual flow since 1964 (1,390 cfs in 1969) and no events exceeding the 2% annual chance flood. The gage at Twin Bridges experienced one event exceeding the 1% annual chance flow (2,200 cfs in 1984) and 3 other events exceeding the 10% annual chance flood.

Figure 1-1: Flooding Source Locations



1.2. Basin Descriptions

The basin description for the Beaverhead River is taken directly from the Pioneer Technical Services (Pioneer) Hydrology Reports (**Reference 4**) that were completed in early 2017. Basin descriptions for the other flooding sources have been added to that description. The Beaverhead River watershed (HUC 8 10020002) contains all of the sub-watersheds for the nine flooding sources. The Pioneer analyses formed the basis of this hydraulic and floodplain mapping investigation and the results are discussed further in Section 2 of this report.

1.2.1 Beaverhead River

The Beaverhead River is a major tributary to the Jefferson River, which is one of three tributary headwaters of the Missouri River located east of the continental divide in southwestern Montana. Originally, the Beaverhead River was formed by the confluence of the Red Rock River and Horse Prairie Creek, which is now inundated by the Clark Canyon Reservoir approximately 23 miles southwest of Dillon (Uthman and Beck, 1998). The construction of Clark Canyon Dam began in 1961 with a date of closure on August 28, 1964. The river tributaries originate in the Beaverhead National Forest near the continental divide and Montana-Idaho border. The watershed is formed by the Pioneer Mountains to the west, Ruby Mountains to the east, and Tendoy, Snowcrest and Blacktail Ranges to the south (Butler and Abdo, 2013). The mainstem Beaverhead River begins at the Clark Canyon Reservoir and flows northeast for approximately 15 miles through the narrow Beaverhead Canyon before entering the upper Beaverhead basin at Barretts (Uthman and Beck, 1998). Rattlesnake Creek and Blacktail Deer Creek join the Beaverhead River near Dillon.

Figure 1-2: Beaverhead River

Approximately 35 miles downstream of Dillon, the Beaverhead River joins the Big Hole River to form the Jefferson River. Just above the confluence of the Beaverhead River and Big Hole River, the Ruby River flows into the Beaverhead River. The entire Beaverhead watershed area encompasses approximately 4,778 square miles. The study watershed basin area from the Clark Canyon Reservoir to the Madison County border is approximately 3,619 square miles.

Figure 1-3: Beaverhead River at Barretts

The Beaverhead River basin elevations within the study area range from approximately 5,100 feet in Dillon to approximately 4,800 feet at Beaverhead Rock (Butler and Abdo, 2013). The overall basin elevations range from 11,000 feet at the continental divide to 4,600 feet near the confluence with the Big Hole River (USACE, 1975). The terrain varies from a high alpine environment in its headwaters to a heavily cultivated landscape in the northern reaches with expansive irrigated pasture lands, bracketed by rolling foothills, and low gradient slough networks. The hydrology of the basin is primarily snowmelt driven that is heavily regulated by the Clark Canyon Reservoir.

Figure 1-5: Beaverhead River at Dillon

Figure 1-4: Beaverhead River near Twin Bridges

Land use in the Beaverhead River basin is primarily agricultural with irrigated farming and ranching operations. Most of the intensely farmed land is located within the Beaverhead River floodplain. Two major irrigation diversions exist on the Beaverhead: the Barretts diversion for the Canyon Ditch and East Bench Canal and West Side Canal near Ten Mile Road. The Barretts Diversion does not provide any flood storage. During the summer and fall, flow in the Beaverhead is heavily reduced due to irrigation operations. Although land use in Beaverhead County and the area around Dillon have historically and currently are primarily dominated by agricultural activities, urbanization in the form of subdivisions and small ranchettes do represent a shift in the land use in and around the City of Dillon. The presence of ranchettes within the Beaverhead River valley currently appear to be primarily in upland areas, but ongoing development may lead to these features to have more prevalence in areas within the valley floodplains. Additionally, one of the areas around Dillon that appears to be experiencing growth and subdividing of larger tracts is the area north of Dillon, in the general vicinity of Guidici Ditch, Murray Gilbert Slough, Selway Slough, and Beaverhead Overbank. As these and other areas are converted from agricultural land use to residential and commercial land use, delineation of the potential flood risk will be critical to minimizing the amount of development that may occur within harm's way.

1.2.2 Beaverhead River Overbank

The Beaverhead River Overbank is located within the Beaverhead River watershed (HUC 8 10020002). This irrigation ditch draws water from the Beaverhead River through a screw-gate diversion structure downstream of the Selway Diversion structure (Section 7, T. 7 S., R. 8 W.). The irrigation ditch runs northeast and passes under Laknar Lane. The surrounding land use is primarily cropland downstream to the end of this study at Webster Lane (Section 5, T. 7 S., R. 8 W.). Some residential properties also border this flooding source. The length of the studied reach is approximately 1.6 miles. Beyond the area of study, the ditch continues downstream in an easterly direction.

Figure 1-6: Beaverhead River Overbank

1.2.3 Dillon Canal

The Dillon Canal is located within the Beaverhead River watershed (HUC 8 10020002). This 1.6 mile irrigation ditch draws flow on the upstream end from Poindexter Slough through a diversion structure (Section 35, T. 7 S., R. 9 W.). The canal runs northeast to deliver water to agricultural fields along the canal. The canal is bordered on the southeast by cropland and on the northwest by montane grassland. After servicing the agricultural fields, the Dillon Canal flows into Blacktail Deer Creek (Section 25, T. 7 S., R. 9 W.).

Figure 1-7: Dillon Canal

1.2.4 Guidici Ditch

The Guidici Ditch is located within the Beaverhead River watershed (HUC 8 10020002). This irrigation ditch draws water from the Beaverhead River through a diversion structure near the Union Pacific Railroad Crossing (Section 7, T. 7 S., R. 8 W.). The ditch runs north adjacent to a mix of residential and industrial properties before traversing cropland at the end of the study area, approximately 1.8 downstream of the diversion (Section 6, T. 7 S., R. 8 W.). The ditch continues downstream beyond the limit of this study.

Figure 1-8: Guidici Ditch

1.2.5 Murray Gilbert Slough

The Murray Gilbert Slough is located within the Beaverhead River watershed (HUC 8 10020002). This flooding source is a 1.2 mile diversion off of the Selway Slough downstream of Dillmont Lane (Section 7, T. 7 S., R. 8 W.). Flowing to the north, the Slough is bordered by light residential development and open space. The slough ends in an area of residential properties (Section 6, T. 7 S., R. 8 W.).

Figure 1-9: Murray Gilbert Slough

1.2.6 Poindexter Slough

Poindexter Slough is located within the Beaverhead River watershed (HUC 8 10020002). The 4.6 mile channel is a relic channel of the Beaverhead River and flows through the Beaverhead River floodplain from south to north. The adjacent landcover is primarily wetland and riparian area, with short sections bordering cropland. Flows in the slough come from three sources – a screw gate diversion structure on the Beaverhead River (Section 3, T. 8 S., R. 9 W.), lateral transfers with the Beaverhead River (with flows entering and leaving Poindexter Slough to the Beaverhead River), and extensive groundwater springs originating from local irrigation (**Reference 7**).

Approximately 2.3 miles downstream of the diversion structure on the Beaverhead River, Poindexter Slough provides water to the Dillon Canal through a screw gate diversion structure. Downstream of the Dillon Canal diversion, Poindexter Slough flows under Interstate 15 through 2 separate bridge structures. Analyses indicate that an under-sized bridge crossing for the railroad immediately downstream of the Dillon Canal diversion headgate results in lateral flow transfers out of Poindexter Slough, along the area bounded by the Union Pacific railroad and Dillon Canal embankments to the Blacktail Deer Creek floodplain. These overflows are represented by the Poindexter Slough Overflow reach included in the hydraulic analyses, which are further complicated by flow exchanges between this overflow and Dillon Canal and Poindexter Slough further down the Poindexter Slough Overflow flowpath. Poindexter Slough rejoins the Beaverhead River at a confluence 1.2 miles downstream of Interstate 15 (Section 26, T. 7 S., R. 9 W.). An additional unnamed canal carries a small amount of irrigation water from a diversion structure on the Poindexter Slough, just downstream of the Union Pacific Railroad crossing. This unnamed channel is not considered as a unique flooding source in this study.

Figure 1-10: Poindexter Slough

1.2.7 Poindexter Slough Overflow

Poindexter Slough Overflow is located within the Beaverhead River watershed (HUC 8 10020002). This flooding source is a 2.0 mile channel originating as an overflow from Poindexter Slough (Section 35, T. 7 S., R. 9 W.) and discharges into the Blacktail Deer Creek floodplain near the Dillon Canal discharge to Blacktail Deer Creek.

1.2.8 Selway Slough

Selway Slough is located within the Beaverhead River watershed (HUC 8 10020002). This flooding source is a 4.9 mile channel originating at a diversion structure on the Beaverhead River (Section 7, T. 7 S., R. 8 W.). This upstream end begins approximately 1/10 of a mile downstream of the Union Pacific and Montana Highway 91 N crossings on the Beaverhead River. Flowing to the northeast, Selway Slough transects a variety of land use types including residential, grassland, riparian/wetland, cropland, and commercial/industrial properties.

At the upstream end of the reach, a number of minor splits and secondary channels convey flow. This study ends 4.5 miles from the diversion in an area of open grassland (Section 32, T. 6 S., R. 8 W.). The Selway Slough continues downstream beyond the end of the study area, eventually rejoining the Beaverhead River. A base level hydraulic analysis is underway for this lower reach.

Figure 1-11: Selway Slough

1.2.9 Stodden Slough

The Stodden Slough is located within the Beaverhead River watershed (HUC 8 10020002). This flooding source receives flow from the combination of a small contributing watershed and split flows off of the Beaverhead River. The channel originates in an agricultural field near Arrigoni Lane off of Montana Highway 41 (Section 8, T. 7 S., R. 8 W.). The channel flows to the northeast for several miles accumulating flow from ephemeral gulches and the Beaverhead River. The land use around the slough is comprised of large wetland and riparian complexes with increasing amounts of agricultural land below Stodden Slough Lane.

Stodden Slough flows into the Beaverhead River at a confluence approximately 0.6 miles upstream of Anderson Lane (Section 22, T. 6 S., R. 8 W.). From headwater to confluence, the slough measures approximately 7.8 miles.

Figure 1-12: Stodden Slough

1.3. Previous Studies

The flooding sources listed in **Table 1-1** were studied in part in the effective Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS). The effective FIS studied portions of Beaverhead River, the Beaverhead River Overbank, Blacktail Deer Creek, Murray Gilbert Slough, Guidici Ditch, Selway Slough, and Stodden Slough with detailed methods. The effective FIS studied portions of the Beaverhead River, Blacktail Deer Creek, Dillon Canal, Carrigan Lane Drainage, and Selway Slough with approximate methods. The effective study of unincorporated county areas was issued on September 30, 1982. The effective study of the City of Dillon was issued on July 5, 1982. The fifteen FIRM panels that will be eventually updated with the hydraulic analysis in this report are included in **Appendix C**. The approximate locations where changes will be made to the Special Flood Hazard Areas (SFHA) are highlighted on the FIRMs. The original hydrologic and hydraulic analysis for the FIS for these flooding sources was performed by Morrison-Maierle, Inc., for FEMA in 1979. The HEC-2 computer program was used for the effective study.

Table 1-4 summarizes the Manning's 'n' values, boundary conditions, and number of structures included in the effective hydraulic models for the six main flooding sources.–This information provides a baseline so users of this report can compare differences between the effective hydraulic models and the updated hydraulic models.

Table 1-4 Effective Hydraulic Modeling Information

Flooding Source	Roughness Values		Boundary Condition	Number of Structures
	Channel	Overbanks		
Beaverhead River	0.035 – 0.040	0.050 – 0.060	Slope-Area Method	8
Beaverhead River Overbank	0.040	0.050	Slope-Area Method	0
Blacktail Deer Creek	0.035 – 0.070	0.038 – 0.080	Slope-Area Method	16
Guidici Ditch	0.035 – 0.040	0.060 – 0.130	Slope-Area Method	2
Murray Gilbert Slough	0.035 – 0.040	0.060 – 0.130	Slope-Area Method	1
Selway Slough	0.035 – 0.040	0.060 – 0.130	Slope-Area Method	3

2. Hydrologic Analysis

Hydrologic analyses for the primary flooding sources in the Beaverhead River watershed were completed by Pioneer Technical Services in the Spring of 2017. Discharges for the 10-, 4-, 2-, 1, and 0.2-percent-annual-chance flood events were established for use in the hydraulic analysis (**Reference 4)**. The hydrologic analysis included a recommendation for the discharges that should be used in the hydraulic model. The watershed work maps from the hydrology reports are included in **Appendix D**.

A summary of discharges from the hydrologic reports is presented in **Table 2-1**. Due to diversions and splits, these discharges are not the final discharges used in the hydraulic model at many locations.

Table 2-1: Discharges Recommended from Hydrologic Analyses

Flooding Source and Location	Peak Discharges (cfs)				
	10-Percent	4-Percent	2-Percent	1-Percent	0.2-Percent
Beaverhead River near Grant, MT (USGS Gage Station 06015400)	1,280	1,570	1,820	2,120	2,990
Beaverhead River at Barretts, MT (USGS Gage Station 06016000)	1,560	1,920	2,250	2,630	3,760
Beaverhead River Above Rattlesnake Creek (Node 200)	1,449	1,829	2,160	2,530	3,592
Beaverhead River at Dillon, MT (USGS Gage Station 06017000)	1,240	1,650	1,980	2,330	3,260
Beaverhead River Above Blacktail Deer Creek (Node 100)	1,240	1,649	1,979	2,328	3,256
Beaverhead River near Dillon, MT (USGS Gage Station 06018000)	1,150	1,460	1,710	1,960	2,590
Beaverhead River near Twin Bridges, MT (USGS Gage Station 06018500)	1,300	1,620	1,870	2,120	2,730

Due to the many split flows, the recommended peak discharges from the hydrologic analyses do not provide a complete representation of the flow changes throughout the watershed. A comprehensive summary of the flow changes for each mapped flooding source, as they were determined and applied in the hydraulic model, is provided in **Appendix H** titled "Cross Section Discharge and Elevation Table". The table includes the cross section in the hydraulic model where each flow change was applied. Flow diagram maps were created to visually show the flow change locations since the system is very complex and many flooding sources are involved in the hydraulic analyses. For more information on split flows and how they impact peak discharges, see **Section 3.3**. The flow diagram maps are included in **Appendix E**.

3. Hydraulic Analysis

3.1. Methodology and Hydraulic Model Setup

Hydraulic modeling was performed using HEC-RAS version 4.1.0 (**Reference 11**). Cross Sections were cut and terrain data was transferred from GIS using CivilGEO's GeoHECRAS software (**Reference 12**). All culverts, bridges, and inline structures were modeled in accordance with the HEC-RAS User's Manual, Version 4.1 (**Reference 13**). In addition, standards listed in FEMA's Knowledge Sharing Site (KSS) (**Reference 14**) were followed to ensure the study meets industry standards.

Two sets of models were created. The first set of models were set up to calculate split flows and diversions. These are broken into three separate regions – one model performing calculations in the upper reaches of the Beaverhead River, one model performing calculations on the middle reaches of the Beaverhead River, and one model performing calculations on the lower reaches of the Beaverhead River.

The second set of models includes the Regulatory and Floodway models. The regulatory model (Plan name = "Beaverhead Regulatory") takes the discharges from the flow calculations models runs the models (with the same geometry). This model plan should be used for regulatory purposes, as well as for determination of the water surface elevations for the 10-, 4-, 2-, 1-, and 0.2 percent annual chance events, as well as the 1-percent-plus simulation. The floodway model (Plan name = "Beaverhead Floodway") contains floodway encroachments and surcharge calculations.

Detailed information on floodway modeling can be found in **Section 3.13** of this report. **Appendix B** contains the Hydraulic Work Maps and **Appendix E** contains the Flow Diagram Maps.

3.2. Field Survey and Topographic Information

Field survey and topographic information was collected using the methods and procedures outlined in FEMA's Guidelines and Specifications for Flood Risk Analysis and Mapping. Specifically, FEMA's Data Capture Technical Reference (**Reference 8**), Guidance for Flood Risk Analysis and Mapping Data Capture - General (**Reference 9**), and Guidance for Flood Risk Analysis and Mapping Data Capture – Workflow Details (**Reference 10**) were adhered to.

3.2.1 LiDAR Collection

Terrain data was collected on April 18, 2013, for the entire study footprint area in the form of Light Detection and Ranging (LiDAR) points by Quantum Spatial (**Reference 3**). The LiDAR deliverables included digital elevation models (DEM) (1-meter resolution), 0.5 meter contours, and a report documentation among other items.

The LiDAR DEM (1-meter resolution) was the primary topographic source for the project and was used, in addition to collected field survey, to develop the HEC-RAS cross-sections.

3.2.2 Field Survey Collection

Bathymetric data collection was necessary to supplement the LiDAR data since the streams are detailed study reaches which require a higher level of data inputs to achieve better modeling results. Detailed hydraulic analyses also require that all structures be included in the modeling unless it can be shown that the structure is not hydraulically significant to the model results. Therefore, field survey was collected.

Ground survey was collected for select riverine cross sections and all hydraulic structures between December 2016 and April 2017 by Morrison Maierle (**Reference 4**). Survey data was collected using GNSS RTK methods of survey. Trimble R8 Model-3 GNSS receivers were used, with Trimble TSC3 survey controllers and Trimble Access software. Channel cross-sections were taken at approximate maximum 1,000 foot intervals. In total, 841 cross sections and 206 structures were surveyed. **Table 3-1** lists the number of cross-section and structure surveys that were completed for each main study reach.

It should be noted that the number of structures surveyed is higher than the number of structures included in hydraulic model. This is because some structures were surveyed on extraneous flowpaths that were determined during hydraulic modeling to be insignificant. Additionally, some hydraulic structures were little more than a plank laying across the stream – these structures would likely be swept away during a flooding event and would not be hydraulically significant, and thus were not included in the hydraulic model.

The field survey data was presented in Montana State Plane 2500 coordinates, North American Datum of 1983 (NAD83-2011). Units are reported in International Feet. Elevations are referenced to the North American Vertical Datum of 1988 (NAVD88). Units are reported in U.S. Feet. GNSS-derived orthometric heights (elevations) were computed using Geoid 12A. These datum and units are identical to those used for the LiDAR calibration control points previously established.

In addition, photographs of each hydraulic structure were taken to assist with the creation of the hydraulic model cross-section geometries. These photographs are included in **Appendix F** of this report. All surveyed hydraulic cross sections and structures were incorporated into the hydraulic model.

Table 3-1: Field Survey Collection Summary

Flooding Source	Number of Hydraulic Structures	Number of Cross Sections
Beaverhead River and Splits	57	369
Beaverhead River Overbank	14	60
Dillon Canal	9	24
Guidici Ditch	21	67
Murray Gilbert Slough	23	75
Poindexter Slough	22	59
Selway Slough	42	123
Stodden Slough	18	64

3.3. Split Flow Analysis

Due to the limited capacity of the primary flooding sources, there are numerous split flows that leave main channels and become flooding sources unto themselves. Some splits only leave during extreme flood events, but others can be expected with some regularity. Each flow where a significant amount of flow would leave the main channel was modeled. (Flow may split in other locations, but will likely be either low discharge or less than 0.5 feet deep). The magnitude of each of the split flows was calculated in HEC-RAS models separate from the regulatory models. **Table 3-2** lists each of these split flows, which flooding source each splits from, and in which model the calculation was made.

Table 3-2: Split Flow Descriptions

Split Flow Name	Splits from	Model Project/Plan	Stream Length (miles)
Beaverhead – Lower Split 1	Beaverhead River	BeaverheadLower_flowcalcs/ Downstream Opt	1.2
Beaverhead – Lower Split 2	Beaverhead River	BeaverheadLower_flowcalcs/ Downstream Opt	1.1
Beaverhead – Lower Split 3	Beaverhead River	BeaverheadLower_flowcalcs/ Downstream Opt	0.9
Beaverhead – Lower Split 4	Beaverhead River	BeaverheadLower_flowcalcs/ Downstream Opt	2.7
Beaverhead – Lower Split 5	Beaverhead River	BeaverheadLower_flowcalcs/ Downstream Opt	0.8
Beaverhead – Lower Split 6	Beaverhead River	BeaverheadLower_flowcalcs/ Downstream Opt	1.3
Beaverhead – Lower Split 7	Beaverhead River	BeaverheadLower_flowcalcs/ Upstream Opt	0.3
Beaverhead – Lower Split 8	Beaverhead River	BeaverheadLower_flowcalcs/ Upstream Opt	0.6
Stodden Slough	Beaverhead River	BeaverheadLower_flowcalcs/ Upstream Opt	7.8
Beaverhead River Overbank	Beaverhead River	BeaverheadMiddle_flowcalcs/ Beaverhead Overbank Flow Calc	1.6
Selway Spill	Beaverhead River	BeaverheadMiddle_flowcalcs/ Guidici-Selway Flow Calc	0.2
Selway Slough	Beaverhead River	BeaverheadMiddle_flowcalcs/ Guidici-Selway Flow Calc	4.9
Murray Gilbert Slough	Selway Slough	BeaverheadMiddle_flowcalcs/ Guidici-Selway Flow Calc	1.2
Guidici Ditch	Beaverhead River	BeaverheadMiddle_flowcalcs/ Guidici-Selway Flow Calc	1.8
Owen Ditch	Beaverhead River	BeaverheadMiddle_flowcalcs/ Owens Flow Calc	1.2
Poindexter Slough	Beaverhead River	BeaverheadUpper_FlowCalc / Beaverhead_Upper_FlowCalc_GatesOpen AND Flow_Calc_DillonClosed	4.6
Poindexter Slough Overflow	Poindexter Slough	BeaverheadUpper_FlowCalc / Flow_Calc_DillonClosed	2.0
Dillon Canal	Poindexter Slough	BeaverheadUpper_FlowCalc / Beaverhead_Upper_Flow_Calc_GatesOpen	1.6

For most split flows, the flows leaving were calculated using the lateral weir function within HEC-RAS. Lateral weir coefficients were carefully selected based on guidance for values recommended by HEC in the document "HEC-RAS 5.0 2D Modeling Users Manual". In general, the weir coefficient values in the hydraulic model correlate to the height and shape of the weir and fall into the ranges given in **Table 3-3**.

Some of the flow calculation model runs produce the HEC-RAS warning, "Flow Optimization Failed to Converge" for certain profiles. This is a common warning for HEC-RAS models with multiple optimized lateral weirs. In these cases, the flow calculations were closely examined to ensure that the model is stable and producing reasonable results that are near convergence.

This network of split flows significantly changes the magnitude of peak discharges for all of the flooding sources. Therefore, the discharge values from the hydrologic analyses were highly modified to account for the impacts of the split flows. The table titled "Cross Section Discharge and Elevation Table" in **Appendix H** contains the correct flooding discharges as modified by the hydraulic split calculations. The flow diagram that illustrates these splits is provided in **Appendix E.**

Table 3-3: Lateral Weir Coefficients

Description	Weir Coefficient Range
Levee/Roadway – 3 ft or higher above natural ground, broad crested weir shape, flow over levee/road acts like weir flow	1.5 to 2.6
Levee/Roadway – 1 to 3 ft elevated above ground, broad crested weir shape, flow over levee/road acts like weir flow but becomes easily submerged	1.0 to 2.0
Natural high ground barrier – 1 to 3 ft high, does not really act like a weir, but water must flow over high ground to get into 2D flow area	0.5 to 1.0
Non elevated overbank terrain – lateral structure not elevated above ground	0.2 to 0.5

3.4. Profile Baseline

The centerlines for all flooding sources were used to define the Profile Baselines and river stationing as the stream distance. The stream stationing for all modeled reaches reference the stream distance in feet above a certain point. **Table 3-4** lists all modeled streams and their stationing references. Additional information on key features along each profile baseline can be found in tables in **Appendix H**.

Table 3-4: Summary of Station References

Flooding Source	Station Reference
Beaverhead River	Feet above limit of study
Beaverhead – Lower Split 1	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 2	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 3	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 4	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 5	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 6	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 7	Feet above confluence with the Beaverhead River
Beaverhead – Lower Split 8	Feet above confluence with the Beaverhead River
Stodden Slough	Feet above confluence with the Beaverhead River
Beaverhead River Overbank	Feet above limit of study
Selway Spill	Feet above confluence with Selway Slough
Selway Slough	Feet above limit of study
Murray Gilbert Slough	Feet above limit of study
Guidici Ditch	Feet above limit of study
Owen Ditch	Feet above limit of study
Poindexter Slough	Feet above confluence with the Beaverhead River
Poindexter Slough Overflow	Feet above the confluence with Blacktail Deer Creek Floodplain
Dillon Canal	Feet above confluence with Blacktail Deer Creek

3.5. Boundary Conditions

The reach boundary conditions were all set using either normal depth water surface elevations, or junctions with other flooding sources. For normal depth boundary conditions, the slope was calculated based on the slope of the channel in the vicinity of the most downstream cross section. For some flooding sources, water surface elevations at the downstream end of the reach will be controlled by backwater from the receiving flooding source.

State Highway 41 crosses the Beaverhead River about 2,500 feet downstream of the study area. The gage upstream of this structure (USGS gage 06018500) indicates that water surface elevations, even during extreme events, are much lower than modeled water surface elevations at the downstream end of the study reach. Therefore, this crossing does not impact the study area. Normal depth boundary condition on the Beaverhead River is appropriate.

Table 3-6 summarizes the boundary conditions used in the analysis.

Table 3-6: Boundary Conditions

Flooding Source	Boundary Condition
Beaverhead River	Normal Depth = 0.003013
Beaverhead – Lower Split 1	Junction with Beaverhead River
Beaverhead – Lower Split 2	Junction with Beaverhead River
Beaverhead – Lower Split 3	Junction with Beaverhead River
Beaverhead – Lower Split 4	Junction with Beaverhead River
Beaverhead – Lower Split 5	Junction with Beaverhead River
Beaverhead – Lower Split 6	Junction with Beaverhead River
Beaverhead – Lower Split 7	Junction with Beaverhead River
Beaverhead – Lower Split 8	Junction with Beaverhead River
Stodden Slough	Junction with Beaverhead River
Beaverhead River Overbank	Normal Depth = 0.001593
Selway Spill	Junction with Selway Slough
Selway Slough	Normal Depth = 0.002105
Murray Gilbert Slough	Normal Depth = 0.002200
Guidici Ditch	Normal Depth = 0.01800
Owen Ditch	Normal Depth = 0.00102
Poindexter Slough	Junction with Beaverhead River
Poindexter Slough Overflow	Normal Depth = 0.003878
Dillon Canal	Normal Depth = 0.003439

3.6. Manning's Roughness Coefficients

Manning's roughness coefficients (Manning's 'n' values) were determined based on aerial imagery and photographs provided by the Morrison-Maierle survey (**Reference 2**).

For channel areas, Manning's 'n' values were set 0.030 to 0.035 for most cross sections. This is indicative of a clean, winding channel with some weeds and stones. At other cross sections, Manning's 'n' values were higher, indicative of timber or brush in the channel. For flooding sources that run along roadways, Manning's 'n' values were set to 0.016, indicative of rough asphalt.

Manning's 'n' values for overbank areas were more variable, to account for different land uses and vegetation growth. At some cross sections, overbank Manning's 'n' values were as low as 0.03, indicative of cultivated areas with field crops. At other cross sections, Manning's 'n' values were set higher, indicative of brush, trees, and undergrowth. At some cross sections, Manning's 'n' values were elevated somewhat higher than the vegetation would indicate to account for other obstructions in the floodplain, such as buildings, garages, or sheds. **Table 3-7** provides a summary of the range of Manning's 'n' values used.

Manning's 'n' values for the inside of culverts were set depending on the material the culvert was made with, as documented in photographs or the surveyor's notes. Values for concrete range from 0.010 to 0.020, while values for corrugated metal range from 0.017 to 0.030. The manning's 'n' for some culverts, which were noted by the surveyor to contain sediment or debris, were modeled to vary between top and bottom to account for this increased roughness.

Table 3-7: Manning's 'n' Values used in Hydraulic Model

Land Use and Description	Range of Manning's 'n' Values
Channel	0.030 – 0.035
Overbanks – natural field	0.030 – 0.050
Overbanks – cultivated	0.030 – 0.045
Overbanks – dense brush and trees	0.100 – 0.120
Overbanks – light brush	0.050
Overbanks – light trees	0.060
Overbanks – medium trees	0.080
Overbanks - hillside	0.030 – 0.060
Overbanks – light commercial and light residential	0.050 – 0.080
Overbanks – highway	0.016

3.7. Development of Cross Sectional Geometries

Cross sectional geometries were established based on the geometry of both the 2016 LiDAR and the 2016 / 2017 field survey. Cross sectional geometries were first taken from the LiDAR using GeoHECRAS (**Reference 12**). At locations where cross section survey was collected, the survey data was superimposed on the cross section at the appropriate location using manual methods.

At cross section locations along the primary flooding sources where survey data was not collected, bathymetric cross section geometry was interpolated between adjacent surveyed cross sections.

For cross sections on the secondary or split flow flooding sources, cross sectional geometries were determined using the LiDAR terrain data only. Given that these flooding sources did not contain water when the LiDAR was collected, bathymetric or survey data would not improve the modeling geometries. Therefore, survey was not collected or used in the model for these flooding sources.

Cross section locations were set using established engineering practice and guidance provided in the HEC-RAS Hydraulic Reference Manual.

Contraction and expansion coefficients were generally set as recommended in the HEC-RAS Hydraulic Reference Manual – 0.1 and 0.3 in areas of gradual transition, 0.3 and 0.5 at typical bridge sections, and 0.6 and 0.8 at locations with abrupt transitions. There are a handful of other cross sections that are not adjacent to hydraulic structures where higher expansion and contraction coefficients are used. These are indicative of rapid contraction or expansion caused by natural land features or man-made embankments.

Bank stations were placed at the boundary between the stream channel and the overbank area – when possible, at a topographic inflection point which divides the stream from the overbank. Due to the unique hydrologic and hydraulic attributes of the Beaverhead River and the split flows, bank stations are higher than most typical riverine studies. In some cases, large flow events fit entirely within the stream channel of the Beaverhead River. This unique river morphology is likely the result of reduced flow discharges over time, related to the construction of the Clark Canyon Dam in the 1960s. High recurrence interval flows are also contained between the bank stations on some of the split flows – this is because the amount of flow in the splits is dictated by hydraulic characteristics, which may allow only a "bank-full" quantity of flow.

During the hydraulic modeling, it was noted that channel thalweg elevations occasionally created seemingly uphill ground surface gradients between cross sections in localized areas. The uphill gradient is typically not significant, and is likely caused by local sediment scour and deposition.

Photographs of select cross sections (adjacent to hydraulic structures) can be viewed in **Appendix F.** The cross section numbering is based on the HEC-RAS river stations and not the river station the cross section was assigned when the field survey was collected. The "Surveyed Structure Stationing Key" table in **Appendix F** provides a cross walk between the HEC-RAS river stations and the survey data. In addition, a "Structures without Photographs" table was included in **Appendix F** to list the structures that do not have photographs to help identify them. Cross section geometries can be viewed in **Appendix G.**

3.8. Hydraulic Structures

Hydraulic structures were modeled in HEC-RAS using established engineering practice and guidance provided in the HEC-RAS Hydraulic Reference Manual. A total of 206 structures were surveyed and are modeled in the hydraulic model, all along the primary flooding sources. A summary of these structures is provided in a table in the "Summary of Modeled Hydraulic Structures" table in **Appendix H**.

Structure geometries were taken from the collected survey data. The photographs, sketches, and spatial data in GIS were all used to most reasonably and accurately model the geometry of each individual hydraulic structure.

Low flow and high flow structure modeling approaches were all determined in accordance with guidance provided in the HEC-RAS Hydraulic Reference Manual. Due to practical spacing limitations, not all hydraulic structures have the standard 4-cross section contraction and expansion placements recommended in the Hydraulic Reference Manual. However, for many structures, cross section 1 and 4 of the recommended approach are not necessary. For example, in the instance of small footbridges that overtop easily, distinct contraction and expansion reaches do not exist in the traditional way. In these areas, the cross section associated with the next upstream or downstream structure is sufficient as a stand-in for the traditional cross section 1 or 4.

Photographs of most hydraulic structures can be viewed in **Appendix F**. Structure and cross section geometries can be viewed in **Appendix G**.

3.9. Non-Conveyance/Blocked Obstruction Areas

Ineffective areas and blocked obstructions were used in the model to restrict flows to areas of cross sections capable of actively conveying flow. Ineffective flow areas were used to model several different hydraulic scenarios:

1. In the vicinity of hydraulic structures, ineffective areas are used in areas that would not actively convey flow due to being blocked by the abutments or the approach to the structure itself. These ineffective areas were placed in accordance with structure modeling guidance provided in the HEC-RAS Hydraulic Reference Manual.

2. For hydraulically disconnected regions, ineffective areas were added to the model to account for the fact that flow would not be actively conveyed in these areas.

3. In overbank areas where flow during flooding events would be minor or insignificant, ineffective areas were used to ensure that accurate hydraulic calculations were taking place in the active, more significant flowpaths. This type of area tended to be a location where flow would not significantly penetrate, such as locations where flow to the lower overbank areas would be mostly blocked by high ground or an embankment near to the bank station.

4. Areas of backwater were modeled as ineffective flow.

5. Areas where the flow would be predominately lateral to the primary direction of flow were modeled as ineffective flow areas. One example of this would be at a cross section where a lateral incoming ditch was picked up along the cross section from the terrain data. These areas of lateral flow would not convey flow effectively in the primary flow direction during a flooding event.

6. Areas near buildings (or in the hydraulic “shadow” of buildings) were occasionally modeled as ineffective areas. This is done to account for areas of flow that would not be active to do the blockage caused by nearby buildings.

Blocked obstructions were also used in the model. These blocked obstructions primarily served two main purposes:

1. Buildings in a cross section were typically modeled as blocked obstructions.

2. Blocked obstructions were also used to block off the "normal" elevation of lakes, ponds, and other localized depressions.

3. Beaverhead – Lower Split 3 was modeled with blocked obstruction in the ditch because it was assumed the ditch would be flowing full and there are a lot of depressions between the main reach of Beaverhead and the ditch that we feel would be filled by the flow before reaching the ditch. The flow would need to breach the berms along the ditch as well before entering the ditch. At most the cross sections along the reach it doesn't show the flow overtopping the berm and flowing into the ditch. The use of blocked obstruction in the ditch appeared to be the reasonable approach along this reach.

All ineffective areas and blocked obstructions were placed in accordance with sound engineering judgment and guidance from the HEC-RAS Hydraulic Reference Manual. In total, 540 cross sections contain either ineffective flow, blocked obstructions, or both. A summary of cross sections with ineffective areas or blocked obstruction, along with reason for the placement of ineffective or blocked areas, is contained in the table titled "Explanation of Ineffective and Blocked Flows" in **Appendix H.**

3.10. Letter of Map Revision and Existing Study Data Incorporation

No LOMRs or any other existing studies were included in this analysis.

3.11. Multiple/Worst Case Scenario Analysis

Reviews of the effective FIRM panels, survey data, and terrain data showed that there are no FEMA accredited levees in the study area.

There were two landforms that were considered to be non-levee features. Non-levee features are structures that cannot be accredited in accordance to the Code of Federal Regulations, Title 44, Chapter 1, Section 59.1 (44 CFR Section 59.1). These two non-levee features are:

- On the right bank of the Beaverhead River, in the vicinity of Owen Ditch. There are also diversion structures in this area that can be closed. For this reason, flow calculations were performed assuming the worst case scenario for each flowpath: For Owen Ditch, the lateral weir is created with the assumption that the diversion structure is open and the non-levee feature fails. For the Beaverhead River, it is assumed that the diversion structure is closed and the non-levee feature remains intact. Hence, the full flow continues on the Beaverhead River in this area.

- Along the left overbank of the Beaverhead River, in the vicinity of Guidici Ditch, Selway Slough, Selway Spill, and Beaverhead River Overbank. There are also diversion structures in this area that can be closed. For this reason, flow calculations were performed assuming the worst case scenario for each flowpath: For Guidici Ditch, Selway Slough, Selway Spill, and the Beaverhead River Overbank, the lateral weir is created with the assumption that the diversion structures are open and the non-levee feature fails. For the Beaverhead River, it is assumed that the diversion structure is closed and the non-levee feature remains intact. Hence, the full flow continues on the Beaverhead River in this area.

As described previously, Poindexter Slough is a flow diversion from the Beaverhead River through a headgate structure and two manually operated headgates. Flows down Poindexter Slough roughly parallel the mainstem Beaverhead River and eventually rejoin the Beaverhead River. Also described previously, Dillon Canal delivers irrigation flows of Beaverhead River water diverted from Poindexter Slough. Flows into Dillon Canal are controlled through two manually operated headgates. Worst case scenario analyses were performed on the Beaverhead River to Poindexter Slough headgate as well as the Poindexter Slough to Dillon Canal headgate to represent worst case conditions on both the Beaverhead River and Poindexter Slough, respectively. A base-case condition is described with both gates open at each diversion headgate (Beaverhead River to Poindexter Slough headgate and Poindexter Slough to Dillon Canal headgate). A description of these worst case analyses follows:

- A worst case scenario for Poindexter Slough is defined as the conditions where base-case flows are entering Poindexter Slough from the Beaverhead River through the open headgates and subsequent lateral transfers, but the Dillon Canal headgates are assumed closed. This routes all the water diverted and transferred into Poindexter Slough from the Beaverhead River past the Dillon Canal headgates and down Poindexter Slough, where they either leave via the Pondexter Slough Overflow, continue down the Poindexter Slough main channel to rejoin the Beaverhead River, or flow back to the Beaverhead River via overbank transfers.
- A worst case scenario for the Beaverhead River between the Poindexter Slough diversion and return to the Beaverhead River is evaluated by evaluating a condition where the headgates controlling flows from the Beaverhead River into Poindexter Slough are assumed closed, and all water flowing past the closed headgates are assumed to continue down the Beaverhead River and floodplain and also provide lateral flow exchanges into Poindexter Slough through overbank flows.

Note that the regulatory model flows represent the worst case scenario results at each cross section in each reach within the portion of the study area between the Poindexter Slough diversion and Poindexter Slough return to the Beaverhead River. Thus, combined total flow of these reaches (Beaverhead River plus Poindexter Slough plus Dillon Canal plus Poindexter Slough overflow) are greater than the published flows within this portion of the Beaverhead River as presented in the Beaverhead County Hydrologic Study report. Additionally, all the flows under these scenarios were evaluated to ensure that they represented worst case conditions and an additional scenario (Dillon Canal headgates closed and Poindexter Slough diversion headgates closed) was not necessary, as the flows in Poindexter Slough immediately above the Dillon Canal diversion were equal to or less than the Poindexter Slough flows with the Poindexter Slough diversion headgates open.

3.12. Model Calibration

There are three USGS stream gages along the studied reach of the Beaverhead River – USGS gages 06016000 (“At Barretts”), 06017000 (“At Dillon”), and 06018000 (“Near Dillon”). Each of these gages were investigated to determine potential data resources for model calibration.

For gages 06016000 and 0601700, gage data was used to calibrate the hydraulic model. For gage 06016000, the March 2017 gage event was used – this event was close to the 50%-annual-chance event. For gage 06017000, the October 2011 gage event was used – this event was between the 50%-annual-chance event and the 10%-annual-chance event. In both cases, Manning’s ‘n’ values and other modeling inputs were modified until the modeled water surface elevations matched the gaged elevations. Overall, the model gave results that were very close to the gage measurements, and only very minor modeling adjustments were necessary. This calibration demonstrates that the hydraulic model is producing reasonable results.

However, gage 06018000 does not contain data which can reasonably be used for calibration purposes. Attempts were made to calibrate the model at this gage using the September 1982 gage event – the most recent year of record for this gage, which was decommissioned in 1983. The hydraulic modeling results for this event are 1.67 feet higher than the gage measured elevation from 1983. The gage was resurveyed to assure the correct gage elevation, and the model was carefully examined in this area – there are no obvious errors that would lead to a discrepancy of this magnitude. It was not possible to adjust model inputs to recreate the 1983 event; therefore, no calibration was performed. It is suspected that natural changes in the stream channel that have occurred since 1983 have significantly altered the stream’s hydraulic characteristics in this area.

3.13. Floodway Analysis

Floodways for all flooding sources with 1-percent-annual chance depths of greater than one foot were all determined using the equal conveyance reduction method. Per state of Montana guidelines, the maximum allowable surcharge at any given cross section is 0.50 feet. The floodway encroachment stations were revised until this requirement was met.

Several notes on the equal conveyance reduction floodways:

- The encroachment stations are set using the HEC-RAS hydraulic modeling program, encroaching on the overbanks on each side of the channel by reducing the conveyance equally on both sides until the target surcharge (0.50 feet) is met.

- When HEC-RAS sets the encroachment stations after the first floodway modeling run, there are frequently surcharges greater than the maximum allowable at many cross sections. The target surcharge is lowered on a cross section-by-cross section basis until the maximum allowable surcharge is not exceeded at any cross section.

- It is generally not possible for the surcharge to be exactly 0.50 feet at all locations. The surcharge is brought as close to the maximum allowable height at each cross section without going over.

- Negative surcharges are occasionally calculated in HEC-RAS. Efforts were made to change the encroachment stationing to remove the negative surcharges. However, some negative surcharges remain. All remaining negative surcharges are no more than -0.04 feet in magnitude (i.e., they can be rounded to zero).

- At some areas where cross sections are close together, the equal conveyance reduction method produces a floodway that is unreasonable due to inconsistent floodway widths between cross sections. The floodway is smoothed by manually moving encroachment stations in the model.

- Because the encroachments are not allowed into the channels of flooding sources, floodways sometimes appear to be unbalanced. However, this is appropriate: if the channel is on the far left side of the floodplain, for example, the left side cannot be further encroached and all encroaching is done on the right side of the floodplain.

- In the vicinity of split flows, the target surcharge was set to zero feet. This was necessary to ensure that the flow distribution is maintained. Encroachment should not be allowed in these split areas because they may impact the flow distribution, and cause significant increases on far downstream on a split.

- Downstream of the City of Dillion the floodway is generally contained along Beaverhead River however to meet the maximum 0.5 ft surcharge a floodway was included along Stodden Slough near the confluence with Beaverhead River and was included along Beaverhead Split 2, Beaverhead Split 5, and Beaverhead Split 6.

3.14. cHECk-RAS

The cHECk-RAS computer program is a tool that can be used to find possible errors in the HEC-RAS hydraulic model. Multiple attempts were made to load the HEC-RAS hydraulic model and perform a cHECk-RAS analysis on the model. However, the project was unable to load following the instructions published in cHECk-RAS Version 2.0.1 User Guide (**Reference 16**). Baker discussed this issue with DNRC and it was decided that cHECk-RAS results will not be included with this hydraulic analysis.

3.15. Other Special Hydraulic Modeling Considerations

- Beaverhead Split 3 was determined to have average flooding depths of less than one foot. Therefore, it is anticipated that this flooding source will be mapped as Zone X shaded, and no profiles have been created.
- For three flooding sources, it was determined that the 1%- and 0.2% annual chance events would be completely contained within the channel for long reaches: Beaverhead River Overbank (downstream of Cross Section 6667), Murray Gilbert Slough (downstream of Cross Section 3762), and Guidici Ditch (downstream of Cross Section 4895). Therefore, it is anticipated that the mapping will contain the note "0.2%-annual-chance event contained within channel". The profiles do not extend to these reaches.
- Based on external QC comments, the entire study reach was evaluated for appropriate representation of hydraulic conditions within the study area. The assessment concluded that cross sections were appropriately placed along the study reaches. However, the assessment did indicate locations where additional cross sections could be added to reduce the overall distance between cross sections. Additional cross sections were added at several locations in several study reaches to reduce the overall distance between cross sections. These cross sections were primarily in the middle and upper reaches of the regulatory model, as well as flow splits within these reaches.

4. Floodplain Mapping

FEMA's KSS and many of FEMA's technical guidance documents were consulted to ensure the mapping meets mandatory requirements necessary to map the results of this study on Beaverhead County's FIRM panels in the future. To create this data set so that it can be incorporated into the Beaverhead County DFIRM, the following guidance documents were used: Data Capture Standards Technical Reference (**Reference 18**), FIRM Panel Technical Reference (**Reference 19**), Mapping Base Flood Elevations on Flood Insurance Rate Maps (**Reference 20**); Metadata (**Reference 21**); Physical Map Revision (PMR) (R**eference 22**); Flood Insurance Rate Map (FIRM) Database (**Reference 23**); and, Flood Insurance Rate Map (FIRM) Graphics (**Reference 24**).

In this section of the report, three different sets of maps are presented to help illustrate the updates to the SFHAs in the study and how these changes impact the community. These maps are discussed in length in **Sections 4.1, 4.3, and 4.4**. For all four sets of maps, the layout and numbering scheme match so that report users can easily compare the information shown on the different work maps.

4.1. Floodplain Work Maps

Floodplain mapping was performed using results from the hydraulic analysis and the 2013 Quantum Spatial LiDAR. The workmaps are included in **Appendix B**, and they show the locations of the 1- and 0.2-

percent-annual-chance flood event floodplain delineations along with the floodway delineations. Water surface elevation data, as well as floodway extents, were extracted from HEC-RAS using GeoRAS, version 10. Geo-RAS was also used to produce rough floodplain delineations. These rough delineations were manually smoothed and adjusted to ensure reasonable floodplain delineations and to account for hydraulic features such as backwater or islands.

At some hydraulic cross sections, mapped floodplain and floodway topwidths may not exactly match modeled floodplain and floodway topwidths. These apparent discrepancies have multiple causes, depending on the cross section. Some of the common reasons for apparent map-model discrepancy include:

- All small islands are removed from the mapping – this is a standard FEMA practice to account for uncertainty around the islands, and because many islands are not visible at the FIRM scale. Large islands in the floodway where the average ground surface is less than 0.5 foot above the BFE were also not mapped, in order to retain floodway capacity.

- Hydraulically disconnected areas, which occasionally impact the model topwidth, are not mapped

- Mapping at a cross section can be influenced by another flooding source

- Differences can be caused by rapid expansion or contraction of the floodplain width in the model – i.e. – one cross section depicts flow wide across the entire low valley of the floodplain, and the next cross section depicts all flow contained in the channel. However, in reality, all flow would not immediately be directed to the channel. In these instances, engineering judgment was used to create a realistic floodplain.

At many locations, engineering judgment was critical in determining the appropriate floodplain and floodway boundaries. Some of the mapping decisions made in certain areas include:

- Beaverhead River, in reaches adjacent and parallel adjacent to Interstate 15 (mostly upstream of Dillon): there are multiple locations where the BFE on the Beaverhead River is higher than the ground elevation on the landward side of the interstate. Since the interstate is a non-levee embankment, it is necessary to show flooding on the landward side. In many of these cases, 1-percent-annual-chance flooding depths would be less than one foot on average, so Zone X shaded mapping is used.
- Locations where the Beaverhead River and Poindexter Slough run close together and frequently mix (from approximately Beaverhead Cross Section 184487 to Cross Section 159915): as determined in the hydraulic analysis, flow exchanges between these two flooding sources are very frequent in this reach. In order to protect the flow exchanges, floodways were liberally delineated. This is necessary to ensure that unacceptable rises in BFE do not occur due to flow being trapped in one flooding source or the other.

- In the area where Guidici Ditch is perched above Murray Gilbert Slough (downstream of Guidici Ditch Cross Section 6987), and where Murray Gilbert Slough is perched above Selway Slough (below Murray Gilbert Slough 6018): Excess flow in this area generally steps downward laterally from Guidici Ditch to Murray Gilbert Slough to Selway Slough. To protect the flow distributions, floodway boundaries were set to the outside toe of the non-levee embankment on the right side of Guidici Ditch and Murray Gilbert Slough. Zone X shaded was used in the connecting areas between these three flooding sources to indicate flooding of less than one foot depth.

4.2. Tie-In Locations

No tie-in to effective SFHAs are necessary in this area – the mapping along the Beaverhead River and Splits entirely encompasses and supersedes effective mapping.

Some tie-in effort will be necessary between Owen Ditch and Black Tail Deer Creek, between the Beaverhead River and Black Tail Deer Creek, and between the upper, enhanced reach of Selway Slough (represented in this study) and the lower, base level reach of Selway Slough.

4.3. Changes Since Last FIRM Mapping – 1-Percent-Annual-Chance Flood Event Comparison

The Changes Since Last FIRM (CSLF) dataset highlights locations where this restudy has resulted in changes to the 1-percent-annual-chance flood event when compared to the effective 1-percent-annual-chance flood event on the effective FIRM. This dataset can quickly show communities areas that were added or removed from the SFHA and is a useful tool for outreach or mitigation activities. The CSLF work maps are included in **Appendix J.** FEMA's Guidance for Flood Risk Analysis and Mapping: Changes Since Last FIRM (**Reference 25**) document was used to help create this product.

4.4. Changes Since Last FIRM Mapping – Floodway Comparison

In addition to the CSLF work maps that show changes in the 1-percent-annual-chance flood event, a separate set of work maps was created to show the changes in floodway delineations between the new and effective studies. The CSLF – Floodway Comparison maps are located in **Appendix K.**

5. Flood Insurance Study

FEMA's KSS (**Reference 14**), Technical Reference: FIS Report (**Reference 16**), and Guidance for Flood Risk Analysis and Mapping: Flood Insurance Study Report (**Reference 17**) were followed to create the products in this section of the report. The 1982 FIS for Beaverhead County was created prior to the release of FEMA's new format guidance, and it is assumed that a future PMR project to incorporate this analysis in the Gallatin County FIS and DFIRM will be produced using the newest specifications. The FIS components included in **Sections 4.1, 4.2, and 4.3** were created using FEMA's latest format specifications.

5.1. FIS Text

The relevant FIS tables have been populated with data from this study and will supersede the information in the 1982 FIS when a PMR project is sponsored. The FIS information is in **Appendix M**.

5.2. Floodway Data Tables

The Floodway Data Tables are in **Appendix N** of this report. Footnotes have been added where appropriate to denote cross sections where special considerations cause differences between the information reported in the Floodway Data Tables, the HEC-RAS model, or the Hydraulic Work Maps.

5.3. Water Surface Elevation Profiles

The water surface elevation profiles depict the 10-, 4-, 2-, 1-, and 0.2-percent annual chance flood events, along with the "1%+" annual chance event are included in **Appendix O** of this report.

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Appendix A
Certification of Compliance

Appendix B
Hydraulic Work Maps

Appendix C
Effective FIRM Maps

Appendix D
Watershed Work Maps

Appendix E
Flow Diagram Maps

Appendix F
Study Area Photographs

Appendix G
Modeled Cross Section Geometries

Appendix H
Hydraulic Analysis Tables

Appendix I
cHECk-RAS

(not included)

Appendix J
Changes Since Last FIRM - 1% Annual Chance Flood Event

Appendix K
Changes Since Last FIRM - Floodway

Appendix L
LOMC Location Map

(not included)

Appendix M
FIS Text

Appendix N
Floodway Data Tables

Beaverhead River and Splits
Enhanced Hydraulic Analysis and Floodplain Mapping Report

Appendix O
Profiles